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Immediate Effect of Cervico-thoracic Mobilization on Deep Neck Flexors Strength in Individuals with Forward Head Posture: A Randomized Controlled Trial

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ABSTRACT

Introduction: Forward head posture is the most frequently observed postural deviations and is said to be associated with shortening of posterior cervical extensors and weakening of the anterior deep cervical flexors. Manual therapy has the potential to achieve reflexogenic changes in muscle and enhance the motor activity and strength.
Purpose of the study: To evaluate the immediate effect of grade IV cervicothoracic Maitland mobilization on deep neck flexors strength in individuals with forward head posture.
Study design: A Single-blinded randomized placebo-controlled trial.
Method: Sixty individuals were randomly divided into two groups. Placebo-controlled (PBO) group (n = 30) received the grade I and experimental (EXP) group (n = 30) received grade IV posteroanterior central and unilateral Maitland mobilization from the upper cervical to the upper thoracic spine.
Outcome measure: Clinical Cranio-cervical flexion test (CCFT) was used to measure the motor activity and the strength of deep neck flexors.
Results: The strength of deep neck flexors effectively increased (p = <0.0001) after advocating grade IV mobilization.
Conclusion: This study concluded that grade IV central and unilateral posteroanterior Maitland mobilization demonstrated significant increase in the deep neck flexors strength in individuals with forward head posture.

KEYWORDS
Maitland mobilization; arthrokinetic reflex (AKR); forward Head Posture (FHP); deep neck flexors (DNF), craniocervical flexion test (CCFT).

1. Introduction

Forward head posture (FHP) is one of the most frequently observed postural deviations[1]. In the last few decades many researchers have reported that factors involving headache, neck pain, and musculoskeletal disorders like temporomandibular disorders and rounded shoulders are incidental to FHP [1–5]. There is a high incidence of postural abnormalities related to cervical, thoracic, head and shoulder alignment that are found to be forward head (66%), kyphotic posture (38%), right rounded shoulder (73%) and left rounded shoulder (66%) in healthy subjects between 20 and 50 years of age[6].

Neck muscles provide support to the neck architecture, and thus a lack of proportion in the neck muscle performance could probably contribute to the development of FHP. FHP is said to be associated with shortening of posterior cervical extensor muscles and weakening of the anterior cervical flexor muscles [4,7]. A vital action of the deep cervical flexor (DCF) muscles is to support deep cervical flexor motion segments that is the craniocervical flexion (CCF)[8]. Hence, deep cervical flexors training is suggested clinically for the management of neck pain that might have been provoked due to forward head posture[9]. As stated above, the anterior lengthened and weakened muscles in forward head posture include the flexors of the neck especially the deep neck flexors (DNF) [8,10].

Several tests and scales have been established to evaluate the DCF function, including the craniocervical flexion test (CCFT), craniocervical flexion dynamometry, electromyographic (EMG) analysis, digital imaging, magnetic resonance imaging, and ultrasonography [11]. The CCFT developed by G. Jull et al [12,13] appears to be an easy, noninvasive, low-load and accepted clinical test to specifically assess and retrain DCF. The test is intentionally low-load to provide the action of the deep flexors in active movements and postures[14]. A study by Sue Hudswell et al [15] used the staged version of the CCFT to indirectly measure the strength of deep cervical flexors using a pressure biofeedback unit. Hudswell stated that it would be a useful tool in the clinical settings to evaluate the motor activity and strength of the deep neck flexors.

The posterior structures of the vertebral column are innervated by branches of the dorsal rami of the spinal nerves, while the intervertebral discs and related

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Supplemental data for this article can be accessed here.

ligaments are innervated by various branches of the ventral rami and sympathetic nervous system. The sinuvertebral nerves are recurrent branches of the ventral rami that reenter the intervertebral foramina to be distributed within the vertebral canal. They are mixed nerves, each formed by a somatic root from a ventral ramus and an automatic root from the gray ramus communicants. Not only this connection, the cervical spine is also innervated by the occipital and the trigeminal nerve branches[16]. Owing to these connections, spinal manual therapy (SMT) of the cervical spine has been demonstrated to have spinal, supraspinal and peripheral effects leading to many therapeutic outcomes[17]. Due to these effects, many mechanisms have come into action depicting the enhancement of the deep neck flexor activity following manual therapy.

One causative mechanism is the regulation of arthrokinetic reflex (AKR) which is used to refer to the tonic and phasic reflex neuromuscular activity, facilitating and inhibiting, arising primarily from the Type I and II articular mechanoreceptors that are situated in the capsuloligamentous structures. [18,19] The ventral and the dorsal spinal nerves innervate these capsuloligamentous structures that surround the cervical spine [16]. These arthrokinetic reflex actions have been hypothesized to occur through the down-regulation of inhibitory input on motor unit activity of the muscles[18].

A joint must have normal mobility in order for its relating muscles to work proficiently. As per Young [20] a muscle can't accomplish its full capacity unless the hindrance from the joints and the surrounding tissue is removed. Joints influence motor unit activation and, therefore, muscle function. The capability of a joint to alter muscle function is mediated by the articular receptors; the articular receptors can inhibit or facilitate muscle. Joint mobilization and manipulation stimulate mechanoreceptors, which may influence the joint and surrounding muscles. [18,19] Forward head posture is claimed to be associated with an increase in upper cervical extension and lower cervical flexion, thus resulting in dysfunction between the upper and lower cervical joints. It is suggested that forward head posture leads to an increase in the compressive forces on the cervical apophyseal joints and posterior part of the vertebra and leads to changes in connective tissue length and strength [21].

Herzog et al [22] exhibited a predictable reflex reaction on the tone of muscles related with spinal manipulative techniques. According to Janda, [23] weakness of a muscle is due to altered motor regulation from the afferent impulses that are relayed from tissues encompassing a dysfunctional joint. This 'pseudo paresis' is a decrease in strength, which occurs when the CNS regulation restrains the full firing of a muscle. One essential objective of mobilization is to improve the extensibility of restricted capsuloligamentous tissue due to which articular mechanoreceptor activation level is affected. Grade III and IV mobilizations at the tissue resistance will cause plastic deformation of collagen in the outermost capsular layer, thereby restoring its normal length and removing the inhibitory influence of the AKR [19]. During mobilization/manipulation of a joint, the capsuloligamentous tissue around it are mechanically stretched restoring its optimal length [18] thus removing inhibitory influence caused by the AKR on the surrounding muscles. This might explain the enhancement in the motor activity and strength of muscles following mobilization.

While some researchers demonstrated the increase in muscle activity with the reflexogenic influence of mobilization others pondered upon the neurophysiologic responses based on spinal, supraspinal, and peripheral mechanisms that could be responsible for these outcomes. Another possible mechanism enhancing the motor activity after mobilization was explained by M. Sterling and his colleagues [24] who studied the effect of grade III mobilization performed to symptomatic C5/C6 segment and demonstrated an improvement in the activation score of deep neck flexors in cranio-cervical flexion test at low-pressure levels of 22 mmHg to 26 mmHg. He stated that this enhancement in the motor activity might be due to initial effects of SMT that activate the descending inhibitory pathways from the dorsal periaqueductal gray area of the midbrain (dPAG) and that their study failed to rule out other possible mechanisms that might lead to this effect.

In the literature, Bialosky et al [17] depicted a comprehensive model in which SMT would be a trigger to initiate several neurophysiologic responses based on spinal, supraspinal, and peripheral mechanisms. According to this model, different responses are attached to specific mechanisms. These mechanisms include the reflex attenuation, periaqueductal gray stimulation (related to the pain modulation), neuromuscular responses, and stimuli of the peripheral nervous system inhibiting inflammatory mediators. He stated that the interaction between all these plausible mechanisms would explain the observed clinical effect. He also claimed that not only the descending inhibitory pathways from periaqueductal gray matter are responsible in the hypoalgesic and in the increased sympathetic activity or the changes in the neuromuscular responses but also stimulation of the mechanoreceptors through SMT is thought to modify α motor neuron excitability levels leading to an increase in muscle activity.

Fabianna R. and her colleagues [25] investigated the changes in the recruitment of the longus colli and sternocleidomastoid measured by ultrasonography in patients with chronic neck pain. The results were noted before and immediately after a single cervical Maitland's grade III posterior-anterior central mobilization technique. Ultrasonographic images of 31 patients with chronic neck pain and matched controls were taken during the 5 phases of the craniocervical flexion test before and after the intervention. Changes in muscle thickness during the test were calculated to infer muscle recruitment. They concluded that cervical mobilization appeared to modulate neck muscles function by increasing deep muscle and reducing superficial muscles recruitment. Their study reported that this effect of the cervical manipulative therapy can either be due to the alteration of the spinal muscle motor neurons excitability or an increase in the sympathetic nervous system activity.

A study conducted by Ethan Liebler [19] et al investigated the effect of grade IV thoracic spine mobilization on lower trapezius strength testing in normal subjects. The treatment group consisted of posteroanterior (P-A) glides performed from T6-T12 at the tissue resistance (grade IV). The control group received grade I assembly consisting of P-A mobilization performed at the beginning of the joint's range, which isn't relied upon to have an articular reflexogenic impact. The isometric muscle strength of the lower trapezius was estimated utilizing a Nicholas manual muscle tester. An independent group t-test comparing the groups demonstrated a statistically significant effect of thoracic spine mobilization on lower trapezius strength testing ($p < 0.05$). He further added that these effects can be due to the removal of the inhibitory responses caused due to the AKR reflex following the Maitland mobilization.

The aim of this study was to evaluate the immediate effect of grade IV cervicothoracic mobilization on deep neck flexors strength in individuals with forward head posture using the craniocervical flexion test. We have focused on deep neck flexors that largely contribute to the segmental stability of the neck architecture and Maitland mobilization implemented to the cervical and thoracic spine with its effect on the motor activity and strength of the paraspinal muscles.

2. Methods

2.1. Study design

A single-blinded, randomized, placebo-controlled trial was used to evaluate the immediate effect of cervicothoracic mobilization on deep neck flexors strength in individuals with forward head posture. This study was conducted at the Mahatma Gandhi Mission's (MGM's) Institute of Physiotherapy, Aurangabad. Students with forward head posture and who were asymptomatic were recruited from the same institute where the study was conducted. Study procedure was initiated after the approval of MGM's Ethics Committee for research on human subjects (MGM-ECRHS/2018/21). Consent was taken in the written form before commencement of the protocol

2.2. Participants and recruitment

The subjects included were 18–30 years of asymptomatic male and female students with forward head posture and Cranio-vertebral angle (CVA) [26] less than 50° on KINOVEA (Angle Measurement Software) [27,28]. Individuals with upper back pain, any cervical condition e.g. spondylosis, radiculopathy, cervical rib etc., flattened cervical spine or decreased cervical lordosis and individuals with any neurological/psychological/skin condition were excluded.

Students who were easily available and who were willing to participate were invited and the eligibility criterion was evaluated accordingly. Block randomization method was used to randomly assign them into two groups by the principal investigator who administered the mobilization. The allocation was concealed with an open list of random numbers. The subjects were randomly assigned to one of the two groups, the placebo-controlled group (PBO) and experimental group (EXP) (Figure 5).

2.3. Blinding

The subjects were blinded to what intervention/grade of mobilization they were going to receive.

2.4. Sample size calculations

A pilot study was conducted to find out the sample size with the same research criteria and outcome measure (Formula: $n = 2\ S^2\ (Z1+\ Z2)^2/(M1\text{-}M2)^2$ where, the mean test intervention (M1) was 15.2, mean control intervention (M2) was 25.6, standard deviation of M1 was 3.03, standard deviation of M2 was 12.8 and the pooled SD (S) was 9.3. Level of confidence (α) was set to be 0.99 and level of power of the test (β) 0.9. Z value associated with alpha was 2.32 and beta was 1.28. Therefore, based on these values the appropriate sample size for this study was calculated to be 60 (30 in each group).

2.5. Procedure

Sixty subjects who were willing to participate in the research were screened with the KINOVEA software to calculate the craniovertebral angle. The picture was taken in lateral view and in standing position[29]. All the subjects were carefully informed about the purpose and the procedure of this study and they had completed the subjective and objective examination according to the data collection sheet provided to

Figure 1. Cranio-vertebral Angle (CVA) using KINOVEA angle-measuring software

them. CVA was measured on KINOVEA software with intersection of two lines, one connecting the tragus of the ear and the spinous process of C7 and the other line is the horizontal from C7 vertebra (Figure 1) [28,30]. Once the CVA angle was evaluated the subjects were randomly assigned to PBO and EXP group and the study was further progressed to the pre interventional evaluation.

2.6. Outcome measure

Cranio-cervical flexion test (CCFT) was used to measure the strength of deep neck flexors with the activation score (AS) and the performance index (PI) calculated in the test, respectively. Pre-intervention values were noted before the commencement of the intervention and post-intervention values were noted immediately following it.

The maximum pressure above the baseline that was achieved and held in a steady manner for 10 seconds was considered as the activation score. PI was calculated by multiplying the pressure increase (from the baseline of 20 mm Hg) by the number of successfully completed 10 second holds [12–14,31] which was documented by the assessor on the data collection sheet.

2.6.1. Instrumentation

This test uses a pressure biofeedback unit (PBU) (Chattanooga Group,Inc, Hixson, TN) consisting of a non-elastic 3-chambered latex pneumatic bag (16.7 × 24 cm), a catheter, and a manometer gauge ranging from 0 to 200 mm Hg with an accuracy of ±3 mm Hg [32] and a stopwatch.

2.6.2. Practice session

The subjects were well elucidated about the craniocervical flexion test (CCFT) [12,15,31]. Firstly, CCFT was demonstrated before the subjects to help them understand what plausible mistakes they might make during the test and then a practice session was held to clear all the doubts and queries before initiating the test. The handling of the pressure biofeedback unit was taught to them according to the Chattanooga group PBU^{TM} manual which was provided with the device[33]. The incorrect strategies such as posterior retraction of the neck (to push the neck directly back on to the air bag), excessive use of superficial neck muscles, jaw clenching, breath holding, and quick jerky nodding movement resulting in overshooting of the target pressure were observed and if any were identified verbal guidance was given to avoid such faulty strategies, and further practice was allowed.

An outcome measure assessor other than the therapist who administered Maitland mobilization was appointed to note the CCFT values to avoid post-intervention-biased results. The assessor who was responsible for carrying out the CCFT received additional training to perfect the skills required to carry out the test.

2.6.3. Preparation

The subjects were positioned with knees flexed (crook position) with the head supported on folded towels so that the neck continued the horizontal line of the body. The Stabilizer pressure biofeedback unit (PBU) was then placed under the suboccipital region and inflated to a pressure of 20 mm Hg in order to fill the space of cervical lordosis. To maintain the neutral starting neck position, necessary layers of towel were placed under the head. The assessor closely observed the subject's performance, and if required, palpation of neck muscles was done to identify incorrect strategies during the CCFT (Figure 2).

2.6.4. Testing procedure

Subjects were required to attempt 10 × 10 seconds hold of upper cervical flexion action or the nodding of head as if they were saying 'yes'. A rest period of 10 seconds was given between holds. The PBU provided feedback and the direction to the patient. The participants were advised to place their tongue on roof of mouth, with lips together and teeth slightly apart, in order to reduce activity of jaw musculature. This was repeated through each 2 mm Hg increment with verbal and visual cueing on correct technique given by the assessor. Controlled factors included consistent positioning of the pneumatic bag under the subject's neck to standardize the contact area. The holding

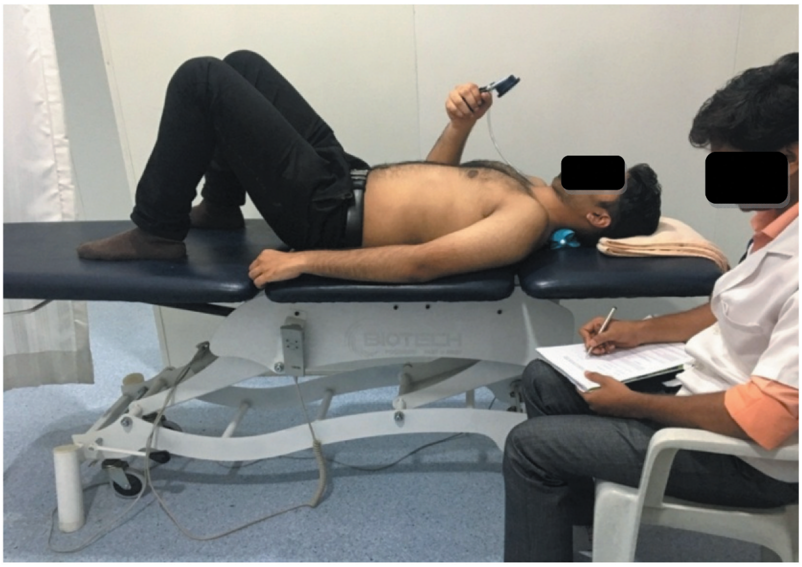

Figure 2. Craniocervical flexion test (CCFT) with the Chattanooga pressure biofeedback unit (PBU) ™.

capacity was measured with a stopwatch. Loss of pressure of greater than 2 mm Hg of the target (dial flickering) or if the pressure was not held steadily or if substitution of the superficial flexors (sternocleidomastoid or anterior scalene) was observed, it was regarded as a failure and the last successful target pressure that recorded was used for data analysis [12,13,15,31].

Verbal and nonverbal communication between the raters and the subjects were not allowed during the test. The assessor assembled the scoring sheets and kept them with him until the end of the study. Throughout testing, the same researcher provided standardized instructions to the subjects and monitored them [12,15,31].

Intra-rater reliability and the inter-rater reliability ranged from moderate to almost perfect agreement for the craniocervical flexion test (ICC ≥ 0.69, ICC ≥ 0.85)[34]. CCFT has demonstrated to have high intra-rater reliability [15,35] Both validity and reliability of this study has been studied by various researchers [11,34,35].

2.7 Interventions

The mobilization was performed taking into consideration the pressure changes and the local variations according to the methods described by Maitland et al [36].The PBO group received the grade I posteroanterior central (Figure 1) and unilateral Maitland mobilization (Figure 2) at the beginning of the range and the EXP group received grade IV posteroanterior central and unilateral Maitland mobilization at the tissue resistance. Central and Unilateral mobilization was implemented to the right and the left side from the first cervical vertebra to the third thoracic vertebra owing to the attachments of the deep neck flexors. The therapist who administered the mobilization was trained under a certified teacher in manual therapy. The therapist was daily supervised by the staff to make sure that she was following the exact treatment protocol. The intervention took place in the manual therapy section of the musculoskeletal department where the study was conducted and on the 3-section manual therapy table. The manual therapy table was adjusted according to the requirement of the therapist who administered the mobilization.

2.7.1. Mobilization of the cervical spine

The subject was positioned in prone. The therapist stood at the head of the patient with her thumbs held in opposition and back to back, with the tips of the thumb pads on the spinous process of the vertebra to be mobilized. The pulp of thumbs of both the hands were used to give a grade I & IV posteroanterior central and unilateral mobilization from first cervical vertebra to the seventh cervical vertebra. The mobilization on the first vertebra was done with the tip of the thumb pads as the first cervical vertebra can rarely be palpated. The first cervical vertebra was mobilized with the presumption that the movement of the overlying

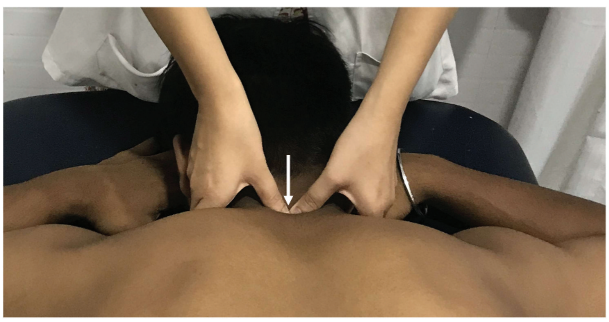

Figure 3. Central PA mobilization and ⇩ indicates mobilization pressure.

Figure 4. Unilateral PA mobilization and the symbol ⇩ indicate mobilization pressure directed postero-anteriorly and slightly medially for the cervical spine.

muscles and ligaments would probably mobilize the vertebra[36]. The second and third cervical vertebra was palpated by asking the individual to tuck his head slightly into more flexion. The unilateral central mobilization was given just 2–3 cm lateral to spinous process against an articular process[36]. Each of the ten segments was mobilized for 1 min (Figures 3 and 4).

2.7.2. Mobilization of the upper thoracic spine

The manual therapy table was adjusted to a lower level in order to mobilize the thoracic spine with the required pressure. For the central P-A mobilization the physiotherapist's position was at the head of the patient with her shoulders over the area to be mobilized to enable the direction of the pressure to be at right angles to the surface of the body. The pads of the thumbs were placed on the spinous process in contact with the upper and lower margins of the same spinous process, pointing transversely across the vertebral column, and the fingers of each hand were spread out over the posterior chest wall to give stability to the thumbs. For unilateral P-A mobilization, the therapist stood toward the patient's shoulder of the side being mobilized to accommodate the necessarily altered angle of the arms[36].

The central pressure to each segment was advocated for 1 min and the unilateral mobilization to both the sides for 1 min individually for cervical and upper thoracic spine. In between the mobilization session, the therapist rested for about 2–3 minutes after

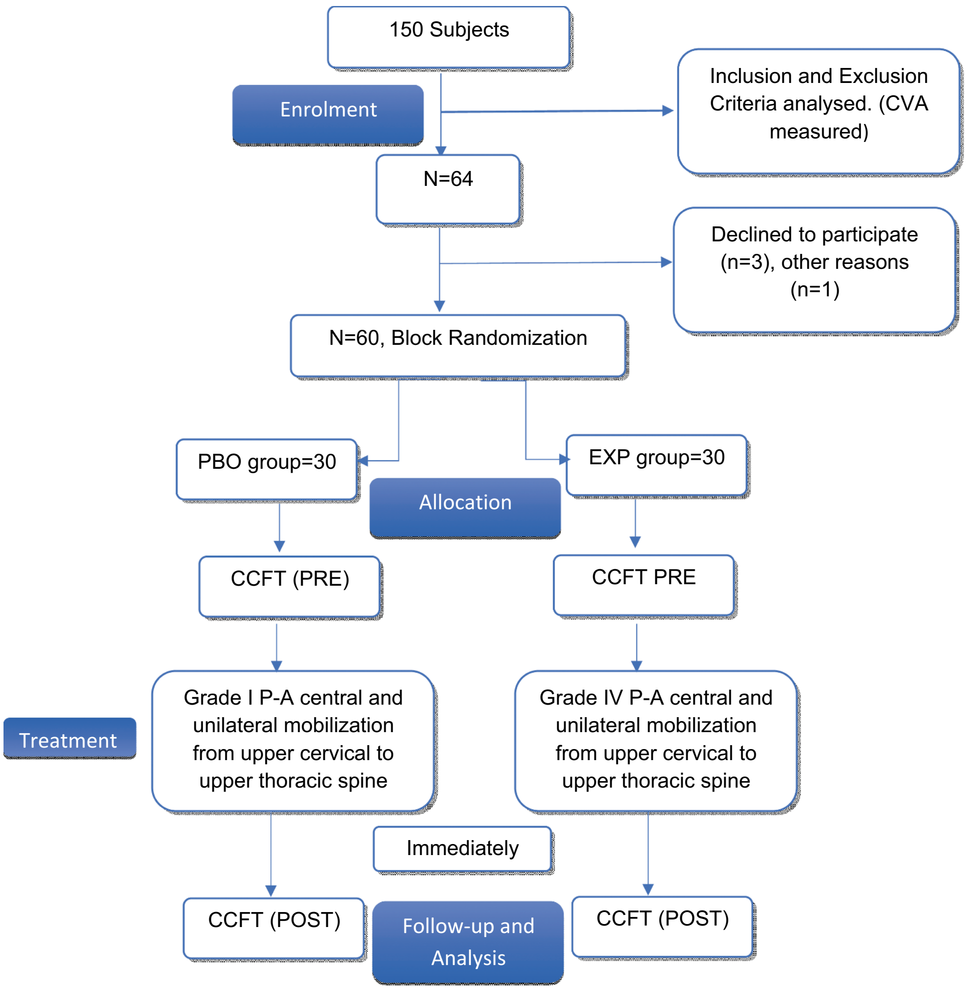

Figure 5. CONSORT flow diagram of participant enrollment, allocation, follow-up & analysis.

applying the central glides to all the segments and then after completing the unilateral glides of one side. The treatment session was of about 35–40 min per subject.

2.8. Statistical analysis

The data were entered in Microsoft Excel and analyzed using Graphpad Prism version 8.0.2(263). Normality of the data was assessed for quantitative variables with the Shapiro–Wilk test. The data which were normally distributed were analyzed using parametric tests, the paired and unpaired t test for intra and inter group data analysis. Data which were not found to be normally distributed were analyzed using non-parametric tests; Wilcoxon and Mann–Whitney U test for intra and inter group analysis. A p value < 0.05 was considered statistically significant.

Table 1. Baseline characteristics of the subjects (n = 60).

Characteristics	PBO group (n = 30)	EXP group (n = 30)	p value
Age (y)	22.1 (1.95)	22.03 (2.20)	0.85
Gender, female (%)	63.3 %	76.66 %	0.33
Height (m)	1.63 (0.09)	1.61 (0.08)	0.36
Weight (kg)	61.2 (13.8)	61.7 (14.0)	0.88
BMI (kg/m2)	22.7 (4.36)	23.3 (4.33)	0.60
CVA	38.2 (5.68)	38.5 (4.28)	0.78

Data are mean (SD) values for age, height, weight, BMI and CVA with student's t test, p value ≤0.05 considered significant. (BMI- Body mass index, CVA- Craniovertebral angle)

Table 2. Pre and post-intervention values (Inter-quartile range) of the activation score (mm Hg) and performance index.

Condition		Pre	Post	p value
Activation Score (AS)	PBO	24 (22.0–26.0)	24 (22.0–26.0)	0.99
	EXP	24 (22.0–26.0)	28 (24.0–28.0)	<0.0001*
Performance index (PI)	PBO	16 (8.0–24.0)	16 (10.0–28.0)	0.51
	EXP	16 (12.0–24.0)	24 (16.0–32.0)	<0.0001*

*(Wilcoxon sign rank test -p value which is ≤0.05; * considered significant)*

3. Results

3.1. Participants flow and recruitment

A total of 150 asymptomatic subjects with forward head posture were assessed for eligibility, of which 64 (22 males, 42 females) fulfilled the inclusion criteria and out of which 60 (18 males and 42 females) agreed to participate further (Figure 5). All subjects completed the study; no one was excluded from analysis. No adverse events were noted during the study. As the results were measured immediately after the intervention was administered, there were no drop-outs. All the 60 subjects were considered while evaluating the results.

3.2. Baseline data

The individual demographic characteristics, age, gender, height, weight, the body mass index (BMI) of all 60 participants are summarized in Table 1.

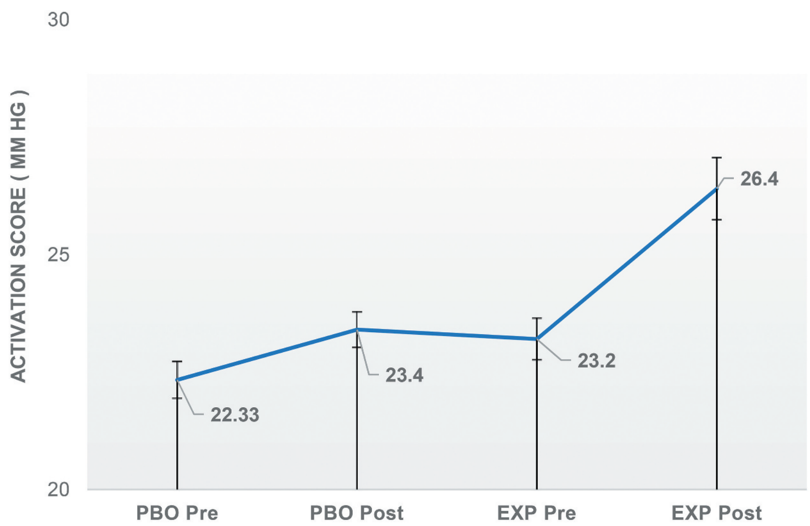

Figure 6. Changes in the pre and post-interventional mean values before and immediately after the intervention (95% confidence interval) of the activation score (mm Hg).

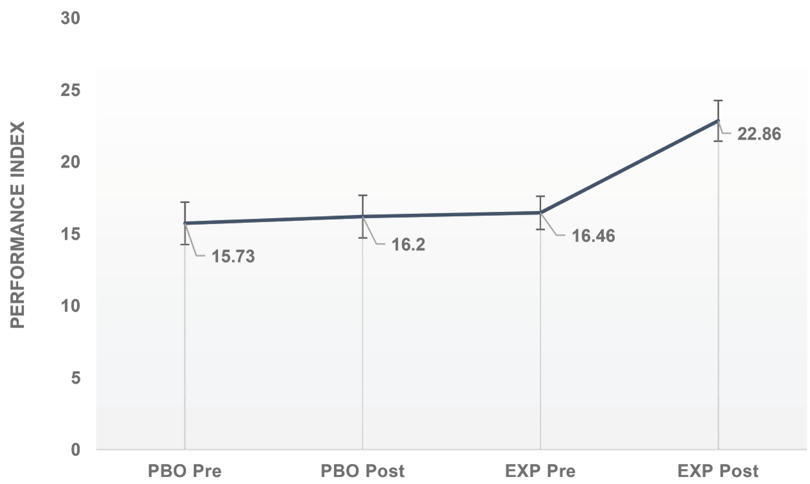

Figure 7. Changes in the pre and post-interventional mean values before and immediately after the intervention (95% confidence interval) of the performance index.

3.3. Effect on deep neck flexors strength

3.3.1. Activation score (AS)

The activation score was evaluated using the non-parametric test, Wilcoxon sign rank test. In the PBO group, the median values for the pre and post-intervention of the activation score were not significant (p = 0.99). In the EXP group, the median values of pre (24.0) and post-intervention (28.0) of the activation score were significant (p = <0.0001) (Table 2.)

The mean difference of the activation score in the PBO group was −0.07 (95% CI, 0.39, 0.37) and in the EXP group was −3.2 (95% CI, 0.44, 0.65) (Figure 6). Cohen's d effect size was calculated to be 2.03.

3.3.2. Performance index (PI)

The performance index was evaluated using the non-parametric test, Wilcoxon sign rank test. In the PBO group, the median values for the pre and post-intervention of the performance index were not significant (p = 0.51). In the EXP group, the median values of pre (16.0) and post-intervention (24.0) of the performance index were significant (p = <0.0001) (Table 2).

The mean difference of performance index in the PBO group was −0.47 (95 % CI, 1.47, 1.48)) and in the EXP group was −6.4 (95% CI, 1.15, 1.41) (Figure 7). The Cohen's d effect size was calculated to be 1.77.

4. Discussion

This study was performed with intention to evaluate the effect of cervicothoracic mobilization on deep neck flexors strength in individuals with forward head posture and it revealed that the group which received the grade IV central and unilateral posteroanterior Maitland mobilization showed significant improvement in the strength of deep neck flexors when compared with the control group. The strength status of deep neck flexors effectively increased after advocating grade IV Maitland Mobilization.

We hypothesized that central and unilateral P-A pressure from C1-T3 might lead to the stimulation of the articular receptors situated in the capsuloligamentous structure leading to an incremental effect on the motor activity and strength of deep neck flexors. Considering the C1 mobilization, the central pressure at the C1 will have a longitudinal directed force vector in posteroanterior direction and unilateral posterior-anterior pressure is more likely to have a rotational force vector that might produce stimulation of the soft tissue structures overlying the C1 vertebra.

The standard error of mean (SEM) value for this study was calculated to be 0.33 for the activation score and 0.72 for the performance index. The minimal detectable change (MDC) values were calculated using these SEM values. The MDC for activation score was calculated to be 0.91 mm Hg (95% CI) and for the performance index the value was 1.98 (95% CI). As previously described, the mean difference for activation score and performance index within the EXP group was 3.2 mm Hg and 6.4, respectively. Considering the above-referred values, the treatment administered was clinically meaningful and the values evaluated were not measurement errors that might occur during the intra-rater CCFT performance.

The current study differs from the study by M. Sterling [24] by implementing grade IV Maitland mobilization owing to its effect on removing the inhibitory influences of the AKR and enhancing the motor activity and strength [18,19] Also the current study included asymptomatic individuals with forward head posture in which the deep neck flexors weakness is evident and cervical mobilization was advocated from the first cervical vertebra to third thoracic vertebra considering the attachments of the deep neck flexors.

Many researchers [37–44] over a period of time revealed that mobilization might lead to enhancement in muscle activity and have gained significant results through their experiments. Scott Yerys and his colleagues [45] determined the usefulness of posteroanterior (P-A) hip joint mobilization in improving strength of the gluteus maximus muscle. He recruited forty subjects to a control group (grade I P-A mobilization) and an experimental group (grade IV P-A mobilization). The subjects performed a pretest/posttest set of five isometric repetitions on the Cybex Norm^{TM} isokinetic machine. This study demonstrated a significant increase ($p = 0.002$) in gluteus maximus strength in response to Grade IV P-A mobilizations performed on the anterior hip capsule.

Karina Yuko Abe et al [46] evaluated the acute effects of Maitland's central posteroanterior mobilization on youth with low back pain. Sixteen women with chronic low back pain were chosen. All volunteers were evaluated according to their perception of pain, their flexibility, mobility, muscular strength and muscular endurance. The intervention protocol was the administration of PA Maitland mobilization on the five lumbar vertebrae, from distal direction to proximal, of 3 series of 1 minute in each vertebra. The Biering-Sorensen test was used to evaluate the isometric endurance of the trunk extensor muscle. The Column lumbar muscle strength assessment was performed with the back dynamometer of Crown®, sit and reach test for lumbar flexibility and modified Schober's test was used to assess the mobility of the lumbar of the lumbar spine. The results revealed that after the administration of PA mobilization there were great improvements in muscular strength (immediate post-treatment and past seven days) and muscular endurance (immediate post-treatment) but there were no significant improvements in the other outcome measures such pain, lumbar flexibility and mobility. On the contrary, a study by Fahed Mehyar [47] and his colleagues who evaluated the immediate effect of lumbar mobilization on activity of erector spinae and lumbar multifidus muscles and revealed that there was only a small significant difference in lumbar multifidus muscle contraction and may not have clinical significance.

4.1. Mechanism of action

As the mobility of a joint is reduced due to any pathology or cause, the integrity of the surrounding capsule and ligaments is compromised leading to an inhibitory reflex called the arthrokinetic reflex. This reflex doesn't allow full firing of the motor units in the muscle fiber. Joint mobilization and manipulation result in the stretching of the compromised capsuloligamentous structures to an optimal level thus removing the inhibitory influence of the arthrokinetic reflex. As the inhibition from the AKR ceases, full firing of all the motor units of the muscle surrounding that joint occurs enhancing its ability to contract [18,19,22,23,45]. The dysfunctional cervical joints in FHP subjects might have compromised the integrity of the surrounding capsuloligamentous tissues. This might have prematurely activated the AKR . As a consequence, the deep neck flexors might be theoretically under neural inhibition caused by this reflex. We hypothesized that the grade IV Maitland mobilizations might have caused the capsule and ligaments to stretch to the optimal thus inhibiting the AKR leading to the recruitment of all the motor units leading to increased muscle function.

Other mechanisms include the periaqueductal gray matter stimulation (related to the pain modulation) that might have led to this response. The study by Bialosky [17] concluded that the observed incremental effect in the motor activity and strength might be due to the interaction between all these plausible mechanisms including the reflexogenic and the all the modulatory mechanisms [17,24,25,44,48]. Therefore it is suggested that greater success in rehabilitation might be achieved through the use of manual techniques, either before or in conjunction with resistive exercises[45].

4.2. Limitations

The strength and the motor activity were measured immediately after the intervention was administered. So, the carryover effect of grade IV Maitland mobilization was not evaluated, which is the key limitation of this study. Second was the exclusion of the symptomatic individuals and lastly, the age group of more than 30 years was not taken into inclusion due to the occurrence of degenerative changes which can lead to provocation of symptoms.

4.3. Future scope

The carry over effect of grade IV Maitland mobilization (mid-term/long-term) and its effect on deep neck flexor motor activity needs to be evaluated in symptomatic subjects. When considering the CCFT, previous researchers demonstrate this test to be less helpful in evaluating the deep neck flexor status in symptomatic individuals. So, it is therefore suggested to select a more appropriate outcome measure to evaluate deep neck flexor motor activity.

4.4. Clinical significance

Clinicians can utilize these findings in everyday practice to improve the muscle activity and strength by integrating manual therapy with the therapeutic exercises.

Maitland mobilization can be used simultaneously with other strengthening programs and training of deep neck flexors with its incremental effect on the motor activity.

5. Conclusion

This study suggested that grade IV central and unilateral posterior-anterior Maitland mobilization seem to have an immediate positive effect on the deep neck flexors strength in individuals with forward head posture. Passive joint mobilizations may be a satisfactory adjunct intervention to counteract the persistent muscle weakness and can be helpful to enhance the deep neck flexors function in addition to the strengthening programs

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